NEW POWER SUPPLIES FOR TRANSPORT LINE–2 QUADRUPOLE MAGNETS IN INDUS

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Abstract

New, high stability, dc current controlled power supplies of rating 25 V, 80 A are developed to energize quadrupole magnets in Transport Line-2 (TL-2) of INDUS. They are developed using two switch forward converter topology operating at 50 kHz. This paper describes design principles, peculiarities in power supply fabrication, salient features and results of various tests conducted on the power supplies.

INTRODUCTION

INDUS-1 and INDUS-2 are the synchrotron radiation sources operational at RRCAT with electron energies of 450 MeV and 2.5 GeV, respectively. The electron beam from the booster is injected through Transport Line-2 (TL-2) into INDUS-1. Existing power supplies for quadrupole magnets in TL-2 are based on 6-pulse controlled rectifier and are being continuously used for past several years [1]. These are being replaced with new, compact, efficient and stable power supplies. Input to the power supplies is 415 V, 50 Hz ac while the output voltage and current ratings are 25 V and 80 A respectively. Stability of output current is ±1000 ppm.

DESIGN PRINCIPLE AND FEATURES

Topology

The newly developed power supplies are based on two switch forward converter topology due to its following distinctive merits [2]:

- Smaller size
- Lighter weight
- Better efficiency
- Simple configuration
- Free from shoot through failure
- High reliability and ruggedness
- Voltage rating of each of the switches is one-half of that in a single switch topology.
- No demagnetizing winding is required.

Switching frequency of 50 kHz is chosen as a good trade-off between size of the power supply and switching losses.

The basic circuit diagram of two switch forward converter is shown in Fig. 1. In this dc-dc converter, IRFX 24N100 MOSFET switches S_1 and S_2 are turned on and off simultaneously causing energy transfer from source to load. The power is coupled to output through a high frequency transformer having turns ratio of 19:2. MUR4100E freewheeling diodes D_1 and D_2 resets the transformer and clamps the voltage across switch to the dc link voltage. DSSK60-015AR dual common cathode diodes D_3 and D_4 functions as secondary rectifier.

Input filter (L_{in}, C_{in}) has cut-off frequency of 70 Hz while output filter (L_{O1}, L_{O2}, C_O, R_d and C_d) is a damped low pass filter with cut-off frequency of 5 kHz. A zeranin shunt of value 1 mΩ is used to sense the output current.

The feedback control scheme consists of two loops: the inner fast voltage loop that corrects input line variations, and outer slow current loop that corrects the drift due to temperature. Bandwidth of voltage loop is 1 kHz while that of current loop is 10 Hz.

Peculiarities in Fabrication

Special arrangements have been made during assembly of components to ensure accessibility to failure-prone components for easy maintenance and replacement. Twisted wires have been used for interconnections to minimize stray inductances. The heat dissipation of losses in power devices is transferred through a water cooled heat sink. Efforts have been made to minimize wiring inductances by using easy pull-out cards with inter-connections on the mother board, providing push buttons,

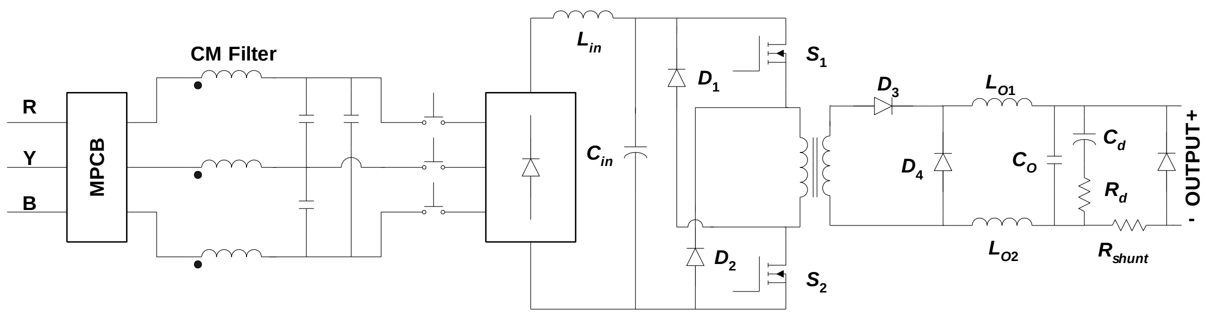

Figure 1: Schematic of two-switch forward converter

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test points and LEDs on fascia plate of the cards.

In front end of dc stage, an in-rush current limit network is incorporated to suppress high surge current during start-up.

Local/Remote Operation and Protections

Each power supply is capable of being operated from local fascia panel or in remote mode from central computer interface via a 25-pin sub-D connector provided on the fascia plate. Various protections like output dc over current, input over current, over temperature of power devices and loss of cooling water flow have been incorporated in design to protect the power supply in case of occurrence of these faults.

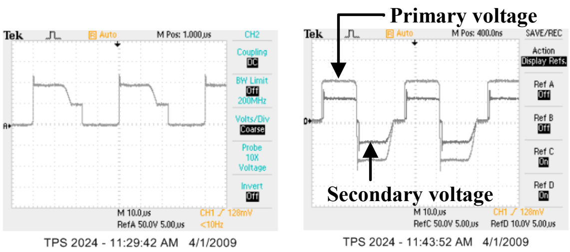
RESULTS AND DISCUSSIONS

Each power supply is housed in a 4U, 19-inch rack as shown in Fig. 2 and they have undergone various tests like:

- Open loop test to check the basic functionality of the power supply.
- Closed loop test to check the stability of control loop.
- Local/Remote operation test which includes testing of all the command, status and analog signals both in local as well as in remote mode.
- Heat run test in which power supply is operated continuously for 10 hrs at full rated power output for 5 days.
- Stability test to measure the stability of output current and ensure that it is within specified limits.
- EMI test to measure conducted EMI and ensure that it is as per CISPR-11 standards.

Figure 3(a) shows switch voltage waveform while Fig. 3(b) shows transformer primary and secondary voltage waveforms.

Figure 2: Front view of power supply



(a) (b)

Figure 3: (a) switch voltage waveform, (b) transformer primary and secondary voltage waveforms

Long term stability of output current was tested to be well within the specified limits. Figure 4 shows the stability curve for 8.5 hrs of continuous operation of power supply after initial warm-up time of 1.5 hrs. Following steps were taken to achieve the required stability:

- A stable shunt made of zeranin is used in the feedback network.
- OP07 precision OPAMPs are used in reference, feedback and error amplifiers.
- Stable MFR resistors are used in reference, feedback and error amplifiers.

Conducted electromagnetic interference (EMI) was measured and pre-compliance was achieved with CISPR-11 norms as shown in Fig. 5, which shows conducted EMI spectrum of the power supply along with CISPR-11 quasi peak and average limit lines.

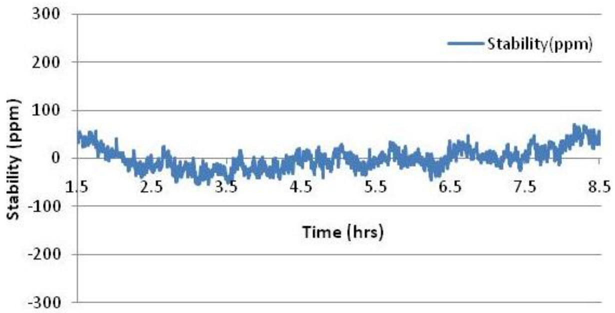


Figure 4: Output current stability of the power supply

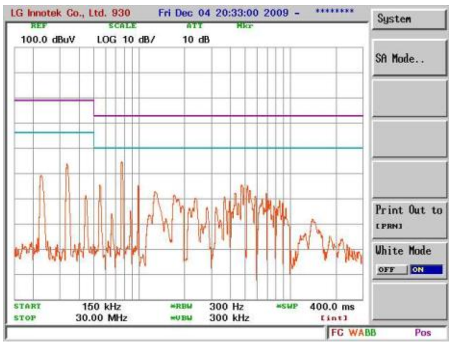


Figure 5: Conducted EMI of the power supply along with CISPR-11 quasi-peak and average limit lines.

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